19-3731; Rev 0; 10/92

MAXIM

Low-Noise Precision Operational Amplifiers

OP27/OP37

General Description

The OP27/OP37 precision operational amplifiers provide lower noise and higher speed with the same input offset and drift specifications as the OP07. Both parts have a 10µV offset, 0.2µV/°C drift, and 1.8 million gain. Coupled with a low-voltage noise of 3.5nV/√Hz at 10Hz and a low 1/f noise corner frequency of 2.7Hz, the OP27/OP37 are optimized for accurate amplification of low-level signals. The OP27 features an 8MHz gain-bandwidth product and a 2.8V/µs slew rate. For applications demanding higher speed, the OP37 has a 63MHz gain-bandwidth product, 17V/µs slew rate, and is stable at gains of five or more.

An output swing of ±10V into 600Ω together with low distortion make the OP27/OP37 ideal for professional audio applications.

For applications requiring greater precision or lower noise than the OP27 or OP37, see the MAX427/MAX437 and the MAX410/MAX412/MAX414 data sheets.

Applications

Low-Noise DC Amplifiers
Microphone Amplifiers
Precision Amplifiers
Tape-Head Preamplifiers
Thermocouple Amplifiers
Low-Level Signal Processing
Medical Instrumentation
Strain-Gauge Amplifiers
High-Accuracy Data Acquisition

Features

- ♦ 10µV Input Offset Voltage
- ♦ 0.2µV/°C Drift
- ♦ 3nV/√Hz Input Noise Voltage (1kHz)
- ♦ 80nV$_{P-P}$ Noise (0.1Hz to 10Hz)
- ♦ 2.8V/µs Slew Rate (OP27)
- ♦ 17V/µs Slew Rate (OP37)
- ♦ 8MHz Gain-Bandwidth Product (OP27)
- ♦ 63MHz Gain-Bandwidth Product (OP37)

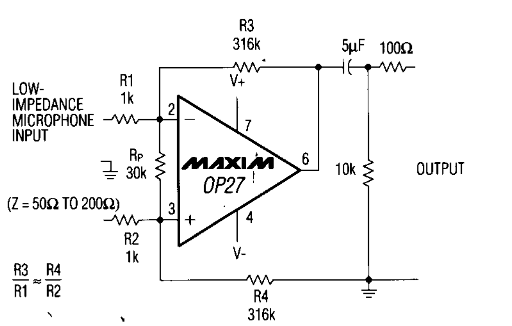
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
OP27EP	0°C to +70°C	8 Plastic DIP
OP27FP	0°C to +70°C	8 Plastic DIP
OP27GP	-40°C to +85°C	8 Plastic DIP
OP27GS	-40°C to +85°C	8 SO
OP27EZ	-40°C to +85°C	8 CERDIP
OP27FZ	-40°C to +85°C	8 CERDIP
OP27GZ	-40°C to +85°C	8 CERDIP
OP27EJ	-40°C to +85°C	8 TO-99
OP27FJ	-40°C to +85°C	8 TO-99

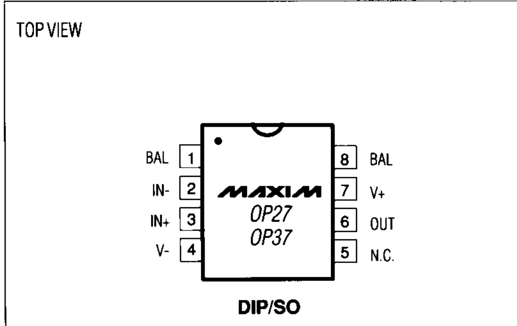
Ordering Information continued on last page.

Typical Application Circuit

LOW-NOISE MICROPHONE PREAMPLIFIER



Pin Configurations



Pin Configurations continued on last page.

Low-Noise Precision Operational Amplifiers

ABSOLUTE MAXIMUM RATINGS

Supply Voltage .... ±22V
Input Voltage (Note 1) .... ±22V
Output Short-Circuit Duration ....Continuous
Differential Input Voltage (Note 2) ....±0.7V
Differential Input Current (Note 2) .... ±25mA
Continuous Power Dissipation (T_A = +70°C)
  Plastic DIP (derate 9.09mW/°C above +70°C) 727mW
  SO (derate 5.88mW/°C above +70°C) 471mW
  CERDIP (derate 8.00mW/°C above +70°C) 640mW
  TO-99 (derate 6.67mW/°C above +70°C) 533mW

Operating Temperature Ranges:
  OP27/OP37EP/FP .... 0°C to +70°C
  OP27/OP37G_/EZ/EJ/FZ/FJ .... -40°C to +85°C
  OP27/OP37A_/B_/C_ .... -55°C to +125°C
Junction Temperature Range .... -65°C to +150°C
Storage Temperature Range .... -65°C to +150°C
Lead Temperature (soldering, 10 sec) .... +300°C

Note 1: For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.
Note 2: OP27/OP37 inputs are protected by back-to-back diodes. Current-limiting resistors are not used in order to achieve low noise. If differential input voltage exceeds ±0.7V, the input current should be limited to 25mA.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_S = ±15V, T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	OP27A/E OP37A/E MIN	TYP	MAX	OP27B/F OP37B/F MIN	TYP	MAX	OP27C/G OP37C/G MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 3)	V_{OS}			10	25		20	60		30	100	µV
Long-Term V_{OS} Stability (Notes 4, 5)	V_{OS}/TIME			0.2	1.0		0.3	1.5		0.4	2.0	µV/Mo
Input Bias Current	I_B			±10	±40		±12	±55		±15	±80	nA
Input Offset Current	I_{OS}			7	35		9	50		12	75	nA
Input Voltage Range	I_{VR}		±11.0	±12.3		±11.0	±12.3		±11.0	±12.3		V
Input Resistance - Differential Mode (Note 6)	R_{IN}		1.3	6		0.94	5		0.7	4		MΩ
Input Resistance - Common Mode	R_{INCM}			3			2.5			2		GΩ
Input Noise Voltage (Notes 5, 7)	e_{np-p}	0.1Hz to 10Hz		0.08	0.18		0.08	0.18		0.09	0.25	μV_{P-P}
Input Noise-Voltage Density (Note 5)	e_n	f_O = 10Hz		3.5	5.5		3.5	5.5		3.8	8.0	nV/√Hz
		f_O = 30Hz		3.1	4.5		3.1	4.5		3.3	5.6	
		f_O = 1kHz		3.0	3.8		3.0	3.8		3.2	4.5	
Input Noise-Current Density (Notes 5, 8)	i_n	f_O = 10Hz		1.7	4.0		1.7	4.0		1.7		pA/√Hz
		f_O = 30Hz		1.0	2.3		1.0	2.3		1.0		
		f_O = 1kHz		0.4	0.6		0.4	0.6		0.4	0.6	
Large-Signal Voltage Gain	A_{VO}	R_L ≥ 2kΩ, V_O = ±10V	1000	1800		1000	1800		700	1500		V/mV
		R_L ≥ 1kΩ, V_O = ±10V	800	1500		800	1500		400	1500		
		R_L ≥ 600Ω, V_O = ±1V, V_S = ±4V (Note 5)	250	700		250	700		200	500		
Output Voltage Swing	V_O	R_L ≥ 2kΩ	±12.0	±13.8		±12.0	±13.8		±11.5	±13.5		V
		R_L ≥ 600Ω	±10.0	±11.5		±10.0	±11.5		±10.0	±11.5		

ELECTRICAL CHARACTERISTICS (continued)

(V_S = ±15V, T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	OP27A/E OP37A/E			OP27B/F OP37B/F			OP27C/G OP37C/G			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Open-Loop Output Resistance	R_O	V_O = 0, I_O = 0		70			70			70		Ω
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±11V	114	126		106	123		100	120		dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4V to ±18V		1	10		1	10		2	20	µV/V
Gain-Bandwidth Product (Note 5)	GBP	f_O = 100kHz, OP27	5.0	8.0		5.0	8.0		5.0	8.0		MHz
		f_O = 10kHz, A_{VCL} ≥ 5, OP37	45	63		45	63		45	63		
		f_O = 1MHz, A_{VCL} ≥ 5, OP37		40			40			40		
Slew Rate (Note 5)	SR	R_L ≥ 2kΩ, OP27	1.7	2.8		1.7	2.8		1.7	2.8		V/µs
		R_L ≥ 2kΩ, A_{VCL} ≥ 5, OP37	11	17		11	17		11	17		
Power Dissipation	PD	V_O = 0		90	140		90	140		100	170	mW
Offset Adjustment Range		R_P = 10kΩ		±4.0			±4.0			±4.0		mV

ELECTRICAL CHARACTERISTICS

(V_S = ±15V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	OP27A OP37A			OP27B OP37B			OP27C OP37C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage (Note 3)	V_{OS}			30	60		50	200		70	300	µV
Average-Offset Voltage Drift (Note 9)	TCV_{OS}			0.2	0.6		0.3	1.3		0.4	1.8	µV/°C
Input Bias Current	I_B			±20	±60		±28	±95		±35	±150	nA
Input Offset Current	I_{OS}			10	50		14	85		20	135	nA
Input Voltage Range	I_{VR}		±10.3	±11.5		±10.3	±11.5		±10.2	±11.5		V
Large-Signal Voltage Gain	A_{VO}	R_L ≥ 2kΩ, V_O = ±10V	600	1200		500	1000		300	800		V/mV
Maximum Output-Voltage Swing	V_O	R_L ≥ 2kΩ	±11.5	±13.5		±11.0	±13.2		±10.5	±13.0		V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±10V	108	122		100	119		94	116		dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4.5V to ±18V		2	16		2	20		4	51	µV/V

Low-Noise Precision Operational Amplifiers

ELECTRICAL CHARACTERISTICS (continued)

(V_S = ±15V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

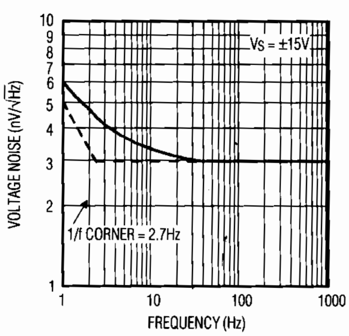
PARAMETER	SYMBOL	CONDITIONS	OP27E OP37E MIN	TYP	MAX	OP27F OP37F MIN	TYP	MAX	OP27G OP37G MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 3)	V_{OS}			20	50		40	140		55	220	µV
Average Offset-Voltage Drift (Note 9)	TCV_{OS}			0.2	0.6		0.3	1.3		0.4	1.8	µV/°C
Input Bias Current	I_B			±14	±60		±18	±95		±25	±150	nA
Input Offset Current	I_{OS}			10	50		14	85		20	135	nA
Input Voltage Range	I_{VR}		±10.5	±11.8		±10.5	±11.8		±10.5	±11.8		V
Large-Signal Voltage Gain	A_{VO}	R_L ≥ 2kΩ, V_O = ±10V	750	1500		700	1300		450	1000		V/mV
Output Voltage Swing	V_O	R_L ≥ 2kΩ	±11.7	±13.6		±11.4	±13.5		±11.0	±13.3		V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±10V	110	124		102	121		96	118		dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4.5V to ±18V		2	15		2	16		2	32	µV/V

Note 3: V_{OS} is measured approximately 0.5 seconds after application of power.
Note 4: Long-term input offset voltage stability refers to the average trend line of V_{OS} vs. Time over extended periods after the first 30 days of operation.
Note 5: Guaranteed by design.
Note 6: Guaranteed by input bias current.
Note 7: See test circuit and frequency response curve for 0.1Hz to 10Hz tester (Figures 1, 6).
Note 8: See test circuit for current-noise measurement (Figure 2).
Note 9: The TCV_{OS} performance is within the specifications unnulled or when nulled with R_P = 8kΩ to 20kΩ. TCV_{OS} is sample tested to 0.1% AQL for A/E grades. B/C/F/G are guaranteed by design.

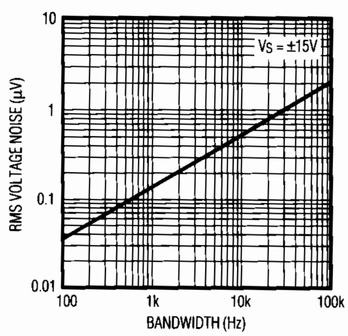
Typical Operating Characteristics

(T_A = +25°C, unless otherwise noted)

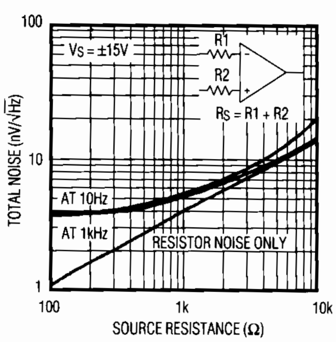
VOLTAGE-NOISE DENSITY vs. FREQUENCY



INPUT WIDEBAND VOLTAGE NOISE vs. BANDWIDTH (0.1Hz TO FREQUENCY INDICATED)

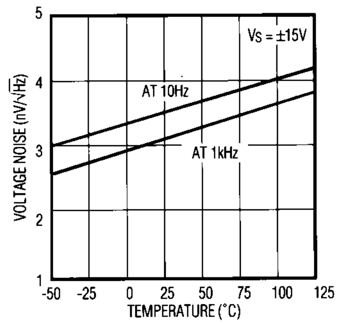


TOTAL NOISE vs. SOURCE RESISTANCE

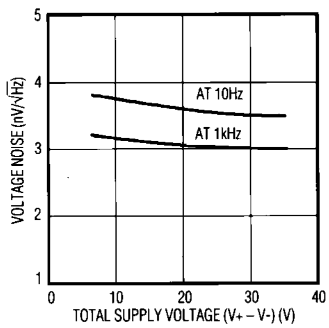


Typical Operating Characteristics (continued)

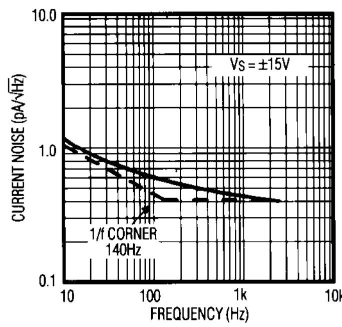
VOLTAGE-NOISE DENSITY vs. TEMPERATURE



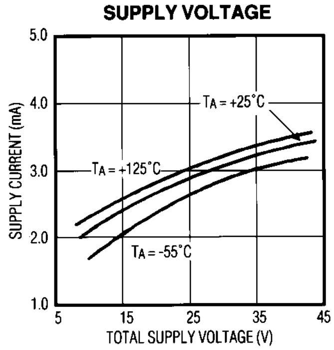
VOLTAGE-NOISE DENSITY vs. SUPPLY VOLTAGE



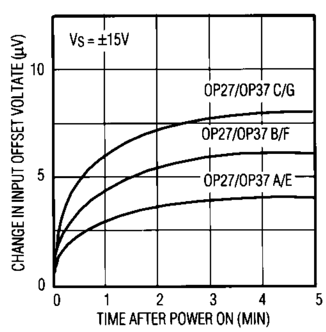
CURRENT-NOISE DENSITY vs. FREQUENCY



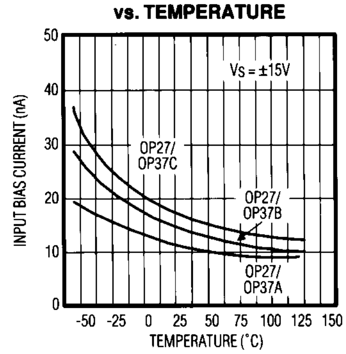
SUPPLY CURRENT vs. SUPPLY VOLTAGE



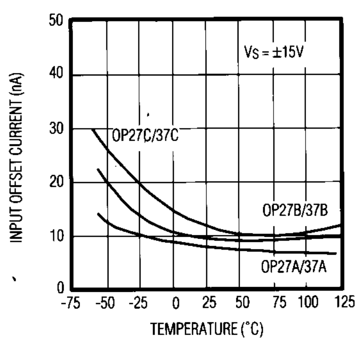
WARMUP OFFSET-VOLTAGE DRIFT



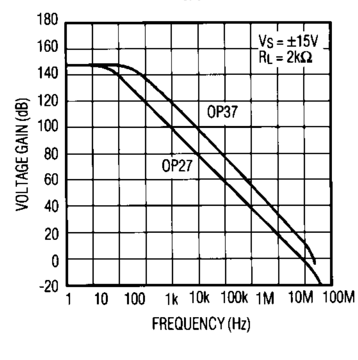
INPUT BIAS CURRENT vs. TEMPERATURE



INPUT OFFSET CURRENT vs. TEMPERATURE

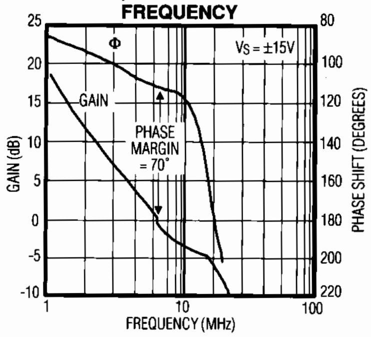


VOLTAGE GAIN vs. FREQUENCY

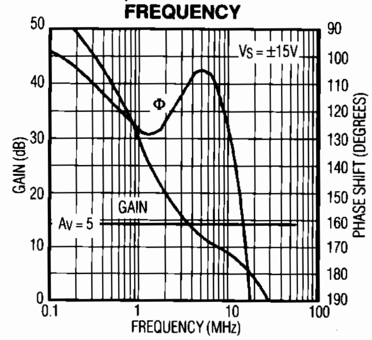


Typical Operating Characteristics (continued)

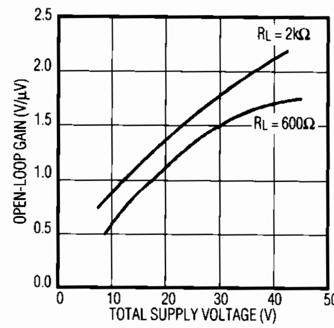
OP27 GAIN, PHASE SHIFT vs. FREQUENCY



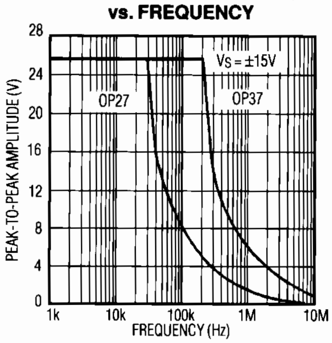
OP37 GAIN, PHASE SHIFT vs. FREQUENCY



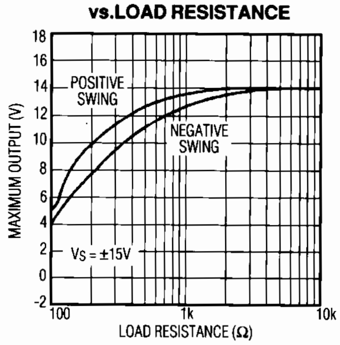
OPEN-LOOP VOLTAGE GAIN vs. SUPPLY VOLTAGE



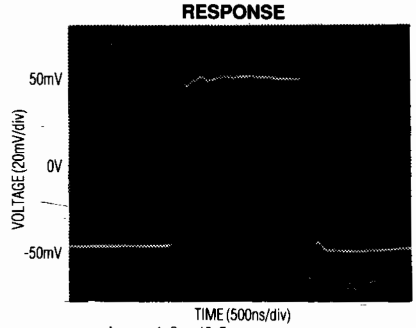
MAXIMUM OUTPUT SWING vs. FREQUENCY



MAXIMUM OUTPUT VOLTAGE vs.LOAD RESISTANCE

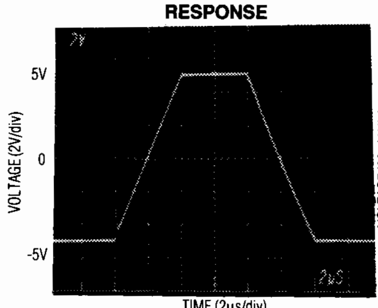


OP27 SMALL-SIGNAL TRANSIENT RESPONSE



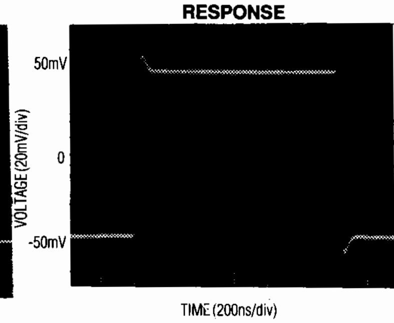
AVCL = +1, CL = 15pF
VS = ±15V

OP27 LARGE-SIGNAL TRANSIENT RESPONSE



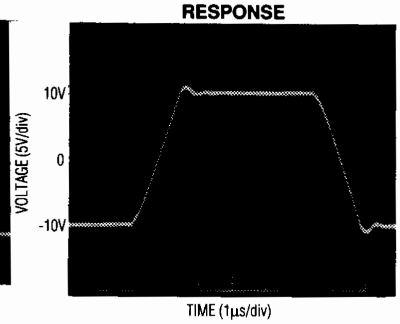
AVCL = +1
VS = ±15V

OP37 SMALL-SIGNAL TRANSIENT RESPONSE



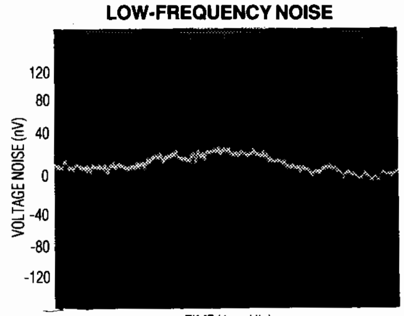
VS ±15V
AV = +5V/V

OP37 LARGE-SIGNAL TRANSIENT RESPONSE



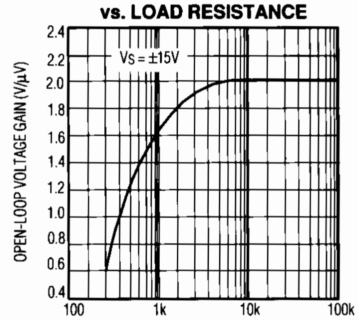
AV = +5V

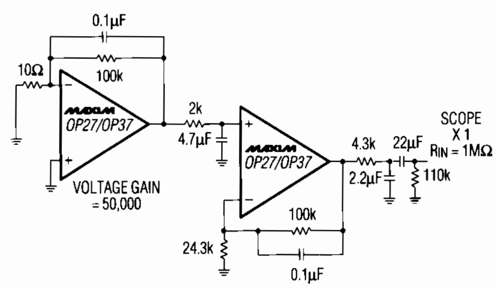
Typical Operating Characteristics (continued)



0.1Hz TO 10Hz PEAK-TO-PEAK NOISE

NOTE: (OSERVATION TIME LIMITED TO 10 SECONDS.)





NOTE: ALL CAPACITOR VALUES ARE FOR NON-POLARIZED CAPACITORS ONLY.

Figure 1. Voltage-Noise Test Circuit (0.1Hz to 10Hz)

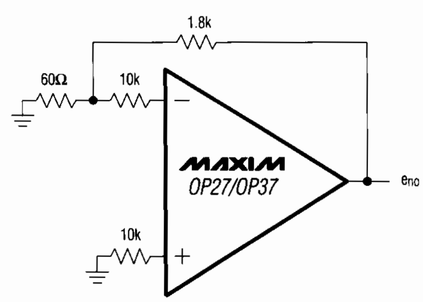


Figure 2. Current-Noise Test Circuit

Applications Information

The OP27/OP37 provide stable operation with load capacitances of up to 2nF and ±10V output swings; larger capacitances should be decoupled with a 50Ω series resistor inside the feedback loop. The OP27 is unity-gain stable and the OP37 is stable at gains of five or greater.

Thermoelectric voltages generated by dissimilar metals at the input terminals degrade the drift performance. Connections to both inputs should be maintained at the same temperature for best operation.

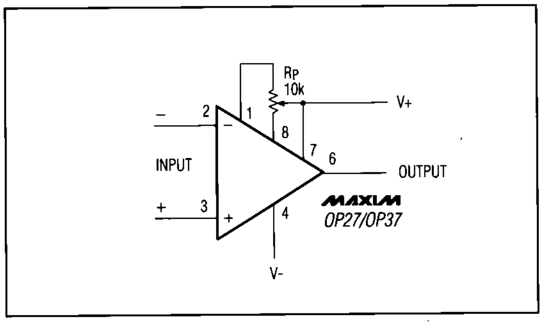


Figure 3. Offset Nulling Circuit

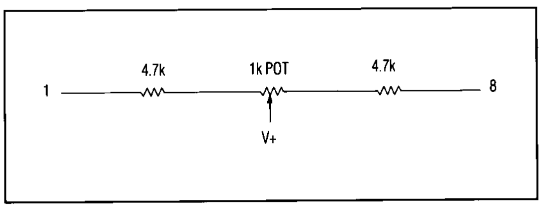


Figure 4. Alternate Offset-Voltage Adjustment

Offset-Voltage Adjustment

Input offset voltage (V_{OS}) is trimmed at the wafer level. If V_{OS} adjustment is necessary, a 10kΩ trim potentiometer (pot) may be used and will not degrade TCV_{OS} (Figure 3). Other trim pot values from 1kΩ to 1MΩ can be used with a slight degradation (0.1µV/°C to 0.2µV/°C) of TCV_{OS}. Adjusting, but not zeroing, V_{OS} creates a drift of approximately (V_{OS}/300)µV/°C. For example, the change in TCV_{OS} is 0.33µV/°C if V_{OS} is adjusted to 100µV. The adjustment range with a 10kΩ trim pot is ±4mV. For a smaller range, reduce nulling sensitivity by connecting a smaller pot in series with fixed resistors; for example, Figure 4 has a ±280µV adjustment range.

Noise Measurements

To measure the 80nV$_{p-p}$ noise specification of the OP27/OP37 in the 0.1Hz to 10Hz range, observe the following precautions:

1. The device must warm up for at least five minutes. Figure 5 shows how V_{OS} typically increases 4µV with increases in chip temperature after power-up. In the 10sec measurement interval, temperature-induced effects can exceed 10nV.

2. For similar reasons, the device must be well-shielded from air currents, including those caused by motion. This minimizes thermocouple effects.

3. As shown in Figure 6, the 0.1Hz corner is defined by only one zero. A maximum test time of 10sec acts as an additional zero to eliminate noise contributions from the frequency band below 0.1Hz.

4. A noise-voltage-density test is recommended when measuring noise on a large number of units. A 10Hz noise-voltage-density measurement correlates well with a 0.1Hz to 10Hz peak-to-peak noise reading, since both results are determined by the white noise and the location of the 1/f corner frequency.

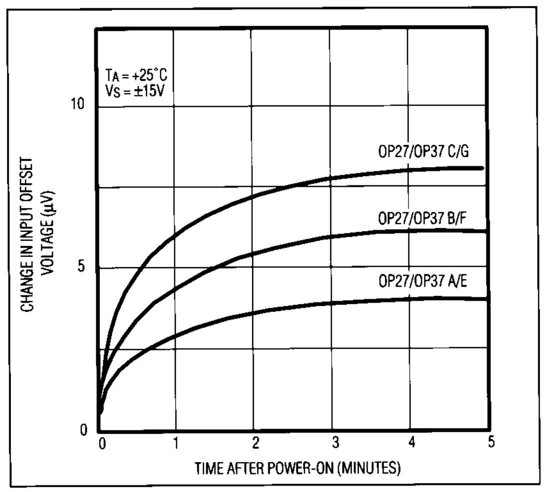


Figure 5. Warm-Up Offset Voltage Drift

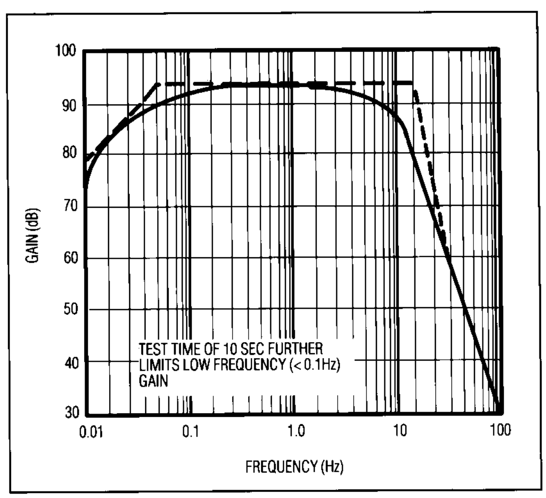


Figure 6. 0.1Hz to 10Hz V_{p-p} Noise Tester Frequency Response

Unity-Gain Buffer Applications (OP27 Only)

Figure 7 shows the circuit and output waveform with R1 ≤ 100Ω, and the input driven with a fast, large signal pulse (>1V).

During the fast rise portion of the output, the input protection diodes short the output to the input, and a current, limited only by the output short-circuit protection, is drawn by the signal generator. With $R_f \geq 500\Omega$, the output is capable of handling the current required ($I_L \leq 20mA$ at 10V) and a smooth transition occurs.

When $R_f \geq 2k\Omega$, a pole created with R_f and the amplifier's input capacitance (8pF) causes additional phase shift and reduces phase margin. A small capacitor (20pF to 50pF) in parallel with R_f eliminates this problem.

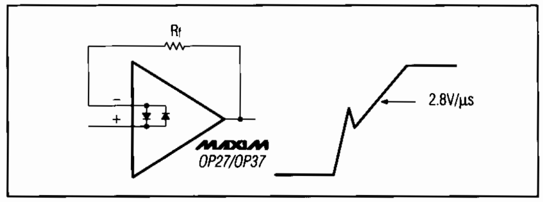


Figure 7. Pulsed Operation of Unity-Gain Buffer

Comments on Noise

The OP27/OP37 are very low-noise amplifiers. They have outstanding input voltage noise characteristics by operating the input stage at a high quiescent current. Input bias and offset currents, which would normally increase with the quiescent current, are minimized by bias-current cancellation circuitry. The OP27/OP37A and E grade devices have I_B and I_{OS} of only ±40nA and 35nA respectively at +25°C. This is particularly important with high source-resistances.

Voltage noise is inversely proportional to the square-root of bias current, but current noise is proportional to the square-root of bias current. The OP27/OP37 low-noise advantages are reduced when high source resistors are used.

Total noise = $[(\text{voltage noise})^2 + (\text{current noise} \times R_S)^2 + (\text{resistor noise})^2]^{1/2}$

Figure 8 shows noise vs. source resistance at 1kHz. To use this plot for wideband noise, multiply the vertical scale by the square-root of the bandwidth. The OP27/OP37 maintains low input noise voltage with $R_S < 1k\Omega$. With $R_S > 1k\Omega$, total noise increases and is dominated by the resistor noise, not the current or the voltage noise. It is only with $R_S \geq 20k\Omega$ that current noise dominates. Current noise is not important for applications with $R_S < 20k\Omega$. The OP27/OP37 has lower total noise than the MAX400/OP07 for $R_S < 10k\Omega$. As R_S increases, the crossover between the OP27/OP37 and the MAX400/OP07 noise occurs in the R_S = 15kΩ to 40kΩ region.

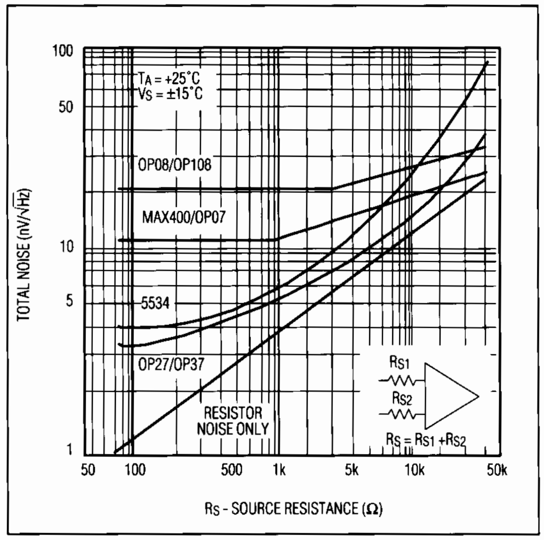


Figure 8. Noise vs. Source Resistance (Including Resistor Noise) at 1kHz

Figure 9 shows 0.1Hz to 10Hz peak-to-peak noise. Here, resistor noise is negligible and current noise (i_n) becomes important, because $i_n \propto 1/\sqrt{f}$. The crossover with the MAX400/OP07 occurs in the R_S = 3kΩ to 5kΩ range, depending on whether balanced or unbalanced source resistors are used (at 3kΩ the I_B and I_{OS} error can be three times the V_{OS} specification). For low-frequency applications, the MAX400/OP07 is better than the OP27/OP37 when $R_S > 3k\Omega$, except when gain error is important. Figure 10 illustrates the 10Hz noise. As expected, the results fall between those of the previous two figures.

For reference, typical source resistances of some signal sources are listed in Table 1.

Low-Noise Precision Operational Amplifiers

Table 1. Signal Source vs. Source Impedance

DEVICE	SOURCE IMPEDANCE	COMMENTS
Strain Gauge	<500Ω	Typically used in low-frequency applications.
Magnetic Tapehead	< 1500Ω	Low I_B is very important to reduce self-magnetization problems when direct coupling is used. OP27 I_B can be neglected.
Linear Variable Differential Transformer	< 1500Ω	Used in rugged servo-feedback applications. Bandwidth of interest is 400Hz to 5kHz.

Table 2. Open-Loop Gain vs. Frequency

OPEN-LOOP GAIN			
FREQUENCY AT:	OP07	OP27	OP37
3Hz	100dB	124dB	125dB
10Hz	100dB	120dB	125dB
30Hz	90dB	110dB	124dB

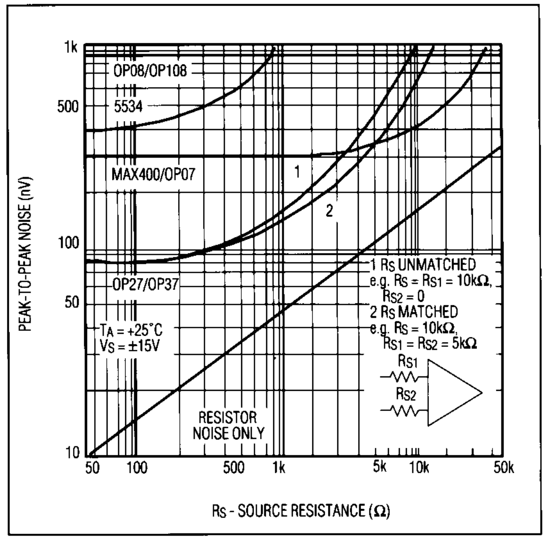


Figure 9. Peak-to-Peak Noise (0.1 to 10Hz) vs. Source Resistance (Includes Resistor Noise)

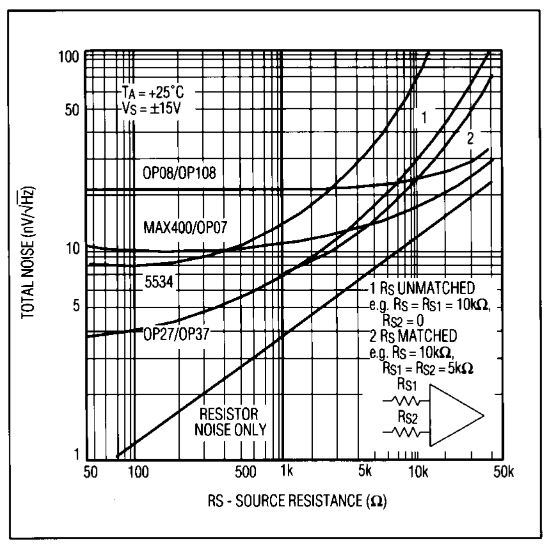


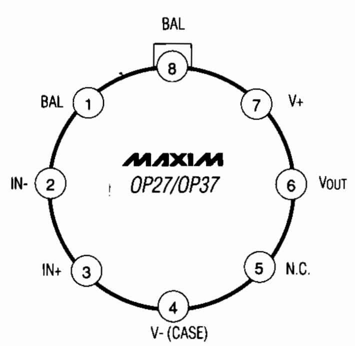
Figure 10. 10Hz Noise vs. Source Resistance (Includes Resistor Noise)

Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE
OP27GJ	-40°C to +85°C	8 TO-99
OP27AZ	-55°C to +125°C	8 CERDIP*
OP27BZ	-55°C to +125°C	8 CERDIP*
OP27CZ	-55°C to +125°C	8 CERDIP*
OP27AJ	-55°C to +125°C	8 TO-99*
OP27BJ	-55°C to +125°C	8 TO-99*
OP27CJ	-55°C to +125°C	8 TO-99*
OP37EP	0°C to +70°C	8 Plastic DIP
OP37FP	0°C to +70°C	8 Plastic DIP
OP37GP	-40°C to +85°C	8 Plastic DIP
OP37GS	-40°C to +85°C	8 SO
OP37EZ	-40°C to +85°C	8 CERDIP
OP37FZ	-40°C to +85°C	8 CERDIP
OP37GZ	-40°C to +85°C	8 CERDIP
OP37EJ	-40°C to +85°C	8 TO-99
OP37FJ	-40°C to +85°C	8 TO-99
OP37GJ	-40°C to +85°C	8 TO-99
OP37AZ	-55°C to +125°C	8 CERDIP*
OP37BZ	-55°C to +125°C	8 CERDIP*
OP37CZ	-55°C to +125°C	8 CERDIP*
OP37AJ	-55°C to +125°C	8 TO-99*
OP37BJ	-55°C to +125°C	8 TO-99*
OP37CJ	-55°C to +125°C	8 TO-99*

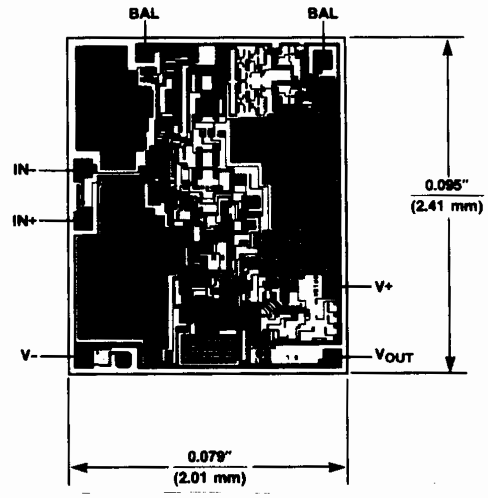
**Contact factory for availability and processing to MIL-STD-883.*

Pin Configurations (continued)



TO-99

Chip Topography

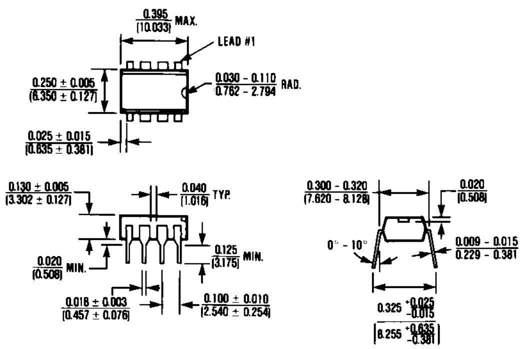


OP27/OP37

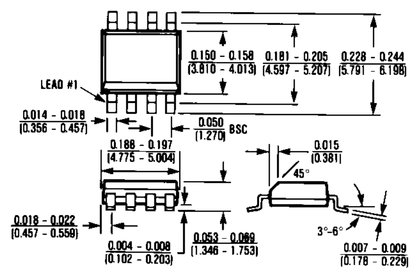
SUBSTRATE CONNECTED TO V-

Low-Noise Precision Operational Amplifiers

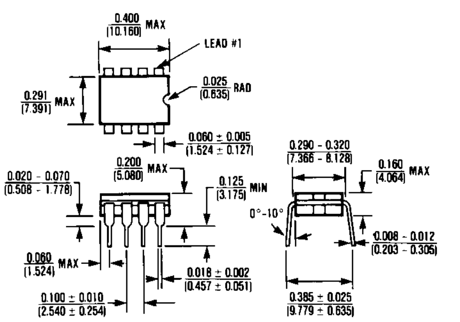
Package Information



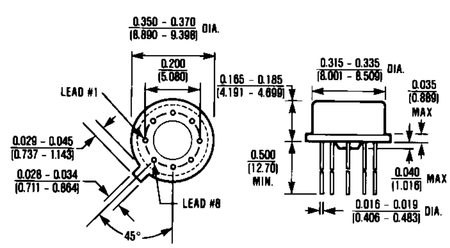
8 Lead Plastic DIP
θ_{JA} = 120°C/W
θ_{JC} = 70°C/W



8 Lead Small Outline
θ_{JA} = 170°C/W
θ_{JC} = 80°C/W



8 Lead CERDIP
θ_{JA} = 125°C/W
θ_{JC} = 55°C/W



8 Lead TO-99
θ_{JA} = 150°C/W
θ_{JC} = 45°C/W